RAPID APPLICATION OF SPACE EFFECTS
FOR THE **SMALL SATELLITE SYSTEMS AND SERVICES SYMPOSIUM**
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Demosthenes Tsairides [(1)], Charles Finley [(2)], George Moretti[(3)]

[(1)] NASA Ames Research Center, Moffett Field, CA 94035, (650) 604-2155,
demosthenes.tsairides-1@nasa.gov
[(2)] NASA Ames Research Center, Moffett Field, CA 94035, (505) 853-666
charles.j.finley@nasa.gov
[(3)]Millennium Engineering and Integration Company, 2201 Buena Vista Drive,
Albuquerque, NM 87106, (505) 715-4101,
gmoretti@meicompany.com

ABSTRACT

NASA Ames Research Center (ARC) has engaged Military Branches, the Department of Defense, and other Government Agencies in successful partnerships to design, develop, deliver and support various space effects capabilities and space vehicles on timeline of need.

Contracts with Industry are in place to execute operational and enabler missions using physical and informational infrastructures including Responsive Manufacturing capabilities and Digital Assurance. The intent is to establish a secure, web-enabled "store front" for ordering and delivering any capabilities required as defined by the users and directed by NASA ARC and Partner Organizations. The capabilities are envisioned to cover a broad range and include 6U CubeSats, 50-100 kg Space Vehicles, Modular Space Vehicle architecture variations, as well as rapid payload integration on various Bus options.

The paper will discuss the efforts underway to demonstrate autonomous manufacturing of low-volume, high-value assets, to validate the ability of autonomous digital techniques to provide Mission Assurance, and to demonstrate cost savings through the identification, characterization, and utilization of Responsive Space components. The culmination of this effort will be the integration of several 6U satellites and their launch in 2016.

READY TO EXECUTE

NASA Ames Research Center (ARC) has engaged like-minded advocates throughout the Military Branches, the Department of Defense, and other Government Agencies to seek out and actively create successful partnerships to invigorate small satellite capabilities and technology base in government laboratories and industry. All aspects of the enterprise have grown from business concepts, innovative acquisition methods, and creative partnerships, to tackling launch to data flow and analysis required to meet the increased demand for small space.

The concept embraced by NASA ARC is also modeled in the engagement of the Operationally Responsive Space (ORS) Office, which is chartered to reach out and drive the small space community forward to reach new levels of responsiveness and performance. The inherent synergies of the offices have been very successful in opening access to space for many new entrants at affordable levels. The responsive and timely nature of the new rideshare capabilities being offered are creating a new market place for launch services that is changing the complexities of launch into the simplicity of catching a city bus. But one doesn't always take the bus, there is still a need to go where and when one desires and not to wait for the bus on a weekend schedule. The ORS Office is now adding the pursuit of "space effects" capabilities to service the customers whether it is a science mission or an operational endeavor.

What is a space effect capability? In most cases the customer is not or should not be interested in the mechanics of how data is collected and provided, the customer should be engaged in the requirements process, defining what is good enough to make decisions or execute as directed by the data collected, provided and analyzed. Critical information required is the timeliness of the data—how stale can it be and still provide actionable information; what phenomenology will provide actionable information—all weather, day/night, wind speed, temperature, chemical content; where does the data need to get to—what are the distribution requirements; how long is the data stream required—is this a fleeting event or long term need. In none of the requirements is a solution spelled out which would then limit the response options. The desired effect is what needs to be carefully thought through and debated. A solutions group can then challenge capabilities to most effectively and judiciously respond to a need.

Long term, costly, and exquisite capability is not the realm of ORS or NASA ARC. There is a need for this kind of capability to reach out into the universe far beyond what would have been believed only a few years ago, or to have an infinite precision offered on very capable satellites. The focus is on small payloads and sensors that can be flown on small delivery systems such as small micro- or nano-satellites or even on stratospheric balloon systems capable of reaching near space "high ground" viewing. The response timeline can be one of the key driving factors in deciding which route to respond with. The 3U or 6U form factor is more readily launched than their larger cousins and sensors on board high altitude balloons are more readily launched than their space age 6U cousins. Of course winds can be tricky and not readily cooperating which is why a robust response capacity able to tap into a variety of capabilities is clearly a path to success.

How rapid the response is can be one of the essential elements of a response. A fleeting event is a challenge for a space system to respond to if the space system is not already in the proper

orbit with the appropriate sensor package. There are several ways to tackle the timeline of need. ORS and NASA ARC have approached the challenge from several angles so as not to be limited to a stove-pipe response. On the launch side, ORS pursued the Super Strypi low cost rocket as one method to achieve timely launches from a variety of potential rail launch locations to hit the desired orbit parameter. Although it did not reach space, the mission demonstrated a collaboration of small satellites capable of being launched on a rapid call up mission. As technical challenges are sorted out, this could become a viable commercial venture for future missions. Another key market change is an exponential number of rideshare opportunities being offered for a reasonable price, which opens the door to space access. The satellite and sensors have also gone through a dramatic shift in performance available to a customer. Just as the cell phone has benefited from (or driven) the miniaturization and innovation of a multitude of components delivering capability beyond the imagination of many now routinely having GPS, accelerometers, a desktop computer like capability, a massive zoom lens for photography in a $1/8^{th}$ inch package. Industry has been able to achieve this within a smaller and smaller package and a drastically reduced power requirement. This illustrates the concept that 6U CubeSat packages can provide substantial capability without sacrificing performance and while benefiting greatly in rapid development and launch timelines.

The technical means are an important aspect of meeting responsive timelines, but it seems that often one of the biggest stumbling blocks is the speed of acquisition—establishing requirements, contracting, securing funding, not changing the requirements or initially overstating them. ORS and NASA ARC have been able to employ a flexible contract structure, Rapid Response Space Works (RRSW) with Millennium Engineering and Integration Company and the Modular Space Vehicle (MSV) contracts with Northrop Grumman, Sierra Nevada Corporation, Orbital ATK, Miltec, and Ball Aerospace. With this contract vehicle in place as an Indefinite Delivery Indefinite Quantity (IDIQ) structure, ORS and NASA ARC have been able to benefit from rapid contracting and delivery of capability.

ORS is currently pursuing development of several operational missions in direct support of a mission user and work to create enabler missions to drive the transformation of space. NASA ARC also pushes the technology for small satellites, launch options, dispenser improvements, and payload capability. Together partnered with others, the small satellite community is transforming both for the government and commercial side and is getting to sit in center stage in exponentially changing how space effects are delivered in a low cost and timely manner.

EVOLUTION

An evolution in technology has enabled significant changes in the approach to small satellite application and construction. Responsive operational missions are becoming a reality through the incorporation and application of modern manufacturing, “Responsive Manufacturing” capabilities delivery with high mission success through leveraging the digital age and harnessing the ubiquitous data stream that exists in the world around us and presenting it for real-time and post archival analysis to ensure our engineering, manufacturing and test processes are sound. ORS has championed the evolution partnering with Millennium Engineering and Integration Company, Raytheon Missile Systems, Applied Minds, and Space Dynamics Lab to achieve a production capability. Essential advances in a host of technologies, has made this

possible. Data search and social media advances continue to push for an instant satisfaction generation that doesn't tolerate waiting for responses or answers—we are transforming users' access to space and satellite data in the decision process of designing, assembling, testing, and operating satellites. The expansion of readily available data storage with fast access for low cost is also changing the way mission assurance is approached—storage capabilities and access to massive amounts of data including video data and machine vision data can be utilized as part of many mission assurance parameters to give a "digital assurance" picture changing our knowledge of the problem from one of quality control simply meeting the check mark to a broad understanding of the flight article in hand with a confidence level that is transforming the garage and lab built CubeSats into reliable assured space vehicles.

After evaluation of alternate manufacturing methods, several technologies are being employed to change the small satellite market into a family of production line units. Through smart employment of Information Technologies, capital investment in tooling and test equipment and robotics, we are achieving successful build demonstrations of multiple products on a single production line. One of the more mundane enabling aspects that is leading to unparalleled success is the smart application of standards across the space vehicles, tooling, test equipment, handling equipment, and analysis tools. The application of standards to the right layers enables the handling of multiple diverse products across a common line. The fight is to drive the non-recurring engineering out of the mundane elements and let innovation occur where it is needed the most in sensor, payload, power, propulsion, etc. vice wasting time and resources reinventing the wheel.

There have been other significant changes in the way we do business that is enabled by the technical advances in digital capability and modern manufacturing. The ability to now test in a 3D environment changes the fundamental assurance of how space vehicles are run through their paces to achieve a high level of confidence or mission assurance. The environment utilizing a precision robot allows for a space vehicle to move through space while detecting and measuring the effects of the motion. It allows for motion through star fields and magnetic fields to check the functionality. In addition, a semi-autonomous assembly and near autonomous test capability removes the variability in technique and procedure concerns.

Another great benefit to the manufacturer is the ability to adapt the capability to multiple product offerings including satellites, terrestrial and aviation products whether it is the whole system or a component. Our current focus is on the 6U market as a demonstrator of the manufacturing and digital assurance response since the satellite is low in cost, adaptable to a multitude of sensors, has sufficient sensor capability to provide useful missions, and has the ability to get launched quickly for a reasonable cost. The evolution will then expand into the larger ESPA class satellites based upon the Modular Space Vehicle architecture developed in partnership with the Air Force Research Lab, Space Dynamic Lab, the Operationally Responsive Space Office, NASA ARC and Northrop Grumman as the prime contractor transitioning the technology to reality. In addition, the systems and infrastructure are being evaluated for application to non-purpose built satellites and components that would benefit from the automation and digital assurance.

We are also advancing the customer interaction working to establish a secure, web-enabled "store front" for ordering and delivering the needed capabilities. The focus will be on allowing a customer to enter the process at a variety of different steps providing flexibility in meeting

customer needs. For example, if the need is ultimately to receive data, then an entire satellite solution including launch and ground operations could be provided with our current structure; if the customer has a sensor that needs to be flown, then a different entry point is established and the option to have either the customer integrate the sensor with deliver a ready to use bus to the customer or have the sensor delivered to the factory for integration and assurance across the production line. In the later scenario, the sensor is just another component that would be managed similarly to the other bus components.

VALIDATION

There are efforts underway to demonstrate the production capability this year and allow an expansion of that capability in the future. A significant challenge to overcome is getting the technology on orbit to prove the viability and feasibility of the concepts. One of the key benefits of the processes described and to be validated this year will be the ability to have an autonomous manufacturing of low-volume, high-value assets at a reasonable cost. We will be able to validate the ability of autonomous digital techniques to provide Mission Assurance to a customer in a manner that before was focused only on quality assurance, limited analysis of a mountain of data, and personnel judgment and persuasion.

CONCLUSION

The culmination of this effort will be the integration of several 6U satellites and their launch in 2017. ORS has been able to execute and are currently developing several operational missions in direct support of a mission user and are now working on continuing to create enabler missions that help drive the transformation of space. NASA ARC also advanced the technology for small satellites, launch options, dispenser improvements, and payload capability. Together partnered with other members of the enterprise, the small satellite community is taking center stage and is playing a significant role in exponentially changing how space effects are delivered in a low cost and timely manner.

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